SYNOPSIS

ON

INTERDEPENDENCE BETWEEN INDIAN AND INTERNATIONAL FINANCIAL MARKETS

For Registration

In

Doctorate of Philosophy in Management

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1. INTRODUCTION

Understanding and modelling the deterministic component which underlies stock market behavior and market perception can be of paramount importance in asset pricing, risk management, policy planning and trading. Risk and return are important concepts of finance. Generally, risk refers to volatility in financial markets which measures the magnitude of the change in prices of a security or an index. There are two kinds of volatility i.e. historical volatility and implied volatility. Historical volatility measures the fluctuations of underlying securities by measuring price changes over fixed periods of time while implied volatility is the market's forecast of a likely movement in a security's price. Implied volatility accounts for future volatility expectations that are expressed in options premiums, while historical volatility measures past underlying securities and index trading ranges. In 1993, the Chicago Board Options Exchange (CBOE) published a measure of implied volatility in the form of a volatility index symbolized as VIX. Initially, VIX is calculated on a minute-by-minute basis from the implied volatilities of eight, at-the-money nearby, second-nearby options on the S&P 100 index (or OEX) options series. The implied volatilities are determined by using the Black-Scholes option pricing model which are weighted in such a manner that the VIX represents the implied volatility of a thirty-calendar day (twenty two trading day) at the money OEX option.

In September 2003, CBOE launched a new VIX derived directly from the option prices of the S&P 500 index. In addition, instead of using only at-the-money call and put options, the new VIX captures the volatility by using a broad range of strike prices of both at-the-money and out-of-money call and put options. In contrast, the latest methodology of calculation is independent of any model of option pricing. Since option prices reflect the market’s expectation of the future volatility over the remaining life of the option. Hence option prices are a vast source of information about future volatility. Volatility indices on index options reflect the general consensus of the expected volatility of the overall market. Higher level of VIX indicates high level of investor’s fear. That’s why the VIX index is also called “investor fear gauge” by **Whaley (2000).** Therefore, market participants consider VIX as the world's leading barometer of investor sentiment and market volatility.

The NSE launched the country's first volatility index, known as India VIX on April, 2008. Indeed, according to **Kumar (2012)**, in the Asian-Australian region, India was the first market with a volatility index computed and disseminated by an organized exchange. India

VIX is a volatility index based on the index option prices of NIFTY. India VIX is calculated based on the best bid and ask quotes of the out-of-the money near and mid-month NIFTY options contracts which are traded on the Future & Option segment of NSE. The calculation methodology of CBOE with suitable amendments to suite the microstructure design of NIFTY options order book is used by NSE to calculate VIX.

In 1991, New Economic Policy of India was launched under the leadership of P. V. Narasimha Rao. This policy opened the door of the India Economy for the global exposure for the first time. New Economic Policy refers to economic liberalization or relaxation in the import tariffs, deregulation of markets or opening the markets for private and foreign players, reduction of taxes to expand the economic wings of the country. The main objective was to plunge Indian economy in to the arena of Globalization and to give it a new thrust on market orientation. Due to economic integration through trade and investment, which has increased correlations between stock markets around the globe, the degree of world stock market integration has increased over the past three decades.

It is being felt that market volatility varies much more than market returns, so the dynamics of market integration and spillover effects can be exposed by inter-market volatility much faster than market returns. Because implied volatility is a more forward-looking measure of volatility, dependency data can help to arrive at a better forecast of volatility for the underlying equity indices by **Sharma *et al.*, (2019).** Different participants of the market depend on various stock exchanges' forward-looking volatility indices, which represent the volatility of the respective stock exchanges. In the short term, volatility indices of different countries could be used for international portfolio diversification and hedging through local market indices would offer great performance. After taking into consideration the above mentioned issues, the proposed study discussed about relationship between implied volatility indexes, stock market return and linkage across volatility indices of international financial markets are studied.

2. REVIEW OF LITERATURE

The implied volatility plays a key role in asset pricing decisions, hedging strategies and portfolio management as it is also a measure of market risk. **Gonzalez-Perez, M. T. (2015)** presented a literature review in which, the study discussed about the most frequent uses of VIX namely, as a financial product to hedge a portfolio against volatility risk; a market risk

measure used to analyze risk flows from financial markets and to relate private and public risks; and a volatility measure to estimate the spot volatility dynamics, the volatility risk premium and volatility jumps. Hence, it is a great concern for investors, portfolio managers, academicians and researchers. It has been extensively analyzed in the literature that the relationship between volatility indices and their underlying stock market return, cross-market relationship and forecasting ability of implied volatility index in developed and emerging economies. The related studies are discussed in detail in this Literature Review.

Fleming *et al.*, (1995) conducted the study to investigate the relationship between VIX; stock markets returns and also evaluate the performance of VIX as a forecast of stock market volatility. The study employed the daily and weekly data of VIX and S&P 100 index for the period 1986 to 1992 and used multiple regression models. The study revealed that there was an existence of large negative contemporaneous correlation between changes in VIX and S&P 100 index return, suggesting an inverse relation between expected volatility and stock market prices. The study also found that the relationship was also asymmetric which indicates that negative stock market moves are associated with changes in the volatility index that are much larger than those associated with positive stock market moves of similar size. The study concludes that VIX performs well as a measure of volatility forecast demonstrating a strong relations with future realized stock market volatility.

Simon, D. P. (2003) worked to explore whether implied volatility reacts differently to positive and negative Nasdaq 100 index return across the period of both the bubble and post-bubble. The study used the daily data of VXN and NDX index over the period from 1995-2002 which was sub-divided between the bubble period (1995-2000) and the post-bubble period (2000-2002). The result of the study showed that the VXN responds in opposite directions to positive and negative NDX returns which is falling with NDX rallies and rising with NDX sell-offs. The results were also stable with the bubble and post-bubble periods. But the results of the asymmetric GARCH model indicate that the conditional volatility of the underlying NDX returns shows no tendency to fall in response to large positive NDX returns. The study also showed the predictive power of VXN and revealed that although the VXN has predictive power for actual volatility but it is a biased forecast of actual volatility.

Low, C. (2004) examined the nature of relationship between option traders' risk perception and contemporaneous market conditions. The study employed the daily data of VIX and S&P 100 index over 1986-1998. The result of the study revealed that risk perception tends to

increase when downside volatility increases more than upside volatility. Moreover, the risk-return relation was asymmetric and non-linear, which is described as a downward slopping reclined S-curve. The study showed that consecutive price falls increases the fear of risk, and consecutive price run-ups somewhat reinforces exuberance by conditioning on the signs of lagged returns. The study concluded that leverage was a plausible but weak non-behavioral explanation for the general negative risk-return relation.

Giot, P. (2005) evaluated the return-volatility relationship between Nasdaq 100 and S&P 100 stock indices and their implied volatility indices namely VXN and VIX by using the OLS method over the period from 1994 to 2003. The study period was sub-divided between low volatility period (1994-1997) and high volatility period (1997-2003). The study showed that there was a strong negative contemporaneous return-volatility relationship for both the Nasdaq 100 and S&P 100 indices. Moreover, the asymmetric return-volatility relation was observed for the S&P 100 index in all cases while the contribution of negative S&P 100 index return was lower for increase in VIX in high volatility period than low volatility period and conversely for decrease in implied volatility. However the asymmetric return-volatility relation was weak for the Nasdaq 100 index and highlighted that the co-movement between return and volatility was muted in high volatility period.

Dennis *et al.*, (2006) worked on daily data of stock returns and implied volatilities of the S&P 100 equity index and 50 large US firms to examine the dynamic relationship between daily innovations in option derived implied volatilities and stock returns from 1988 to 1995. The results of the study highlighted that the relation between index-level volatility innovations and index returns is highly negative in comparison to the relation between individual stock return and the respective firm-level volatility innovations. Furthermore, the negative relation between individual stock returns and index-level volatility innovations is notably stronger than the negative relation between individual stock returns and their respective firm-level volatility innovation. The results also revealed that the relationship between stock returns and innovations in systematic volatility (idiosyncratic) volatility is substantially negative (near zero). The study suggested that the asymmetric volatility is primarily attributed to systematic market-wide factors rather than aggregated firm-level effects. The study also provides evidence which indicates that the daily changes in both firm and index level implied volatilities contain reliable incremental information about the future volatility of respective stock or index.

Hibbert *et al.*, (2008) discussed the short-run dynamic relations between the Nasdaq100 (S&P 500) index return and changes in implied volatility VXN (VIX) at both the intraday and daily level data. The study was based on the daily data of volatility indices and their underlying indices over the period from 1998-2006 for the VIX and from 2001-2006 for VXN and 5-min & 30-min intraday data from 2003-2006. The study revealed a significant negative and asymmetric relation between innovation in returns and implied volatility of stock indices which is consistent with the behavioral explanation of the relations. The results also show the superiority of employing the new VIX (VXN) to examine the return-volatility relation compared to either the contemporaneous realized volatility or the near-the-money implied volatility. The study concluded that the presence and magnitude of the negative relation and asymmetry between return and implied volatility were most closely associated with extreme changes in index returns.

Frijns *et al.*, (2010) presented the study to examine the properties of the Australian implied volatility index with respect to contemporaneous stock index returns and the forecasting power of AVX for future volatility for both in-sample and out-of-sample analysis. The study used the daily data of AVX and S&P/ASX 200 index returns for the period from 2002 to 2006 by using regression analysis. The study found that AVX has a significant negative and asymmetric relationship with S&P/ASX 200 returns. The study also revealed that the AVX contained important information for both in-sample and out-of-sample. In the case of in-sample, it showed that the inclusion of AVX in the GJR-GARCH model highlighted that the implied volatility contained important information beyond the GARCH model. The result of out-of-sample analysis, it has been observed that AVX has the highest forecasting power relative to the GJR-GARCH model and Risk metrics approach, with its highest forecasting power at the one-month forecasting horizon.

Chiang, S. M. (2012) worked on the magnitude of return as well as volatility transmission between NASDAQ-100 (S&P 500) and VXN (VIX) by employing bivariate GARCH model with threshold effect. The study used the daily price data of the S&P 500, NASDAQ-100, VIX and VXN indices over the period from 2001 to 2011. The study documented the performance of VIX was the best but its volatility was also higher than other index during the whole sample period. Moreover, only lagged negative return (change) have a bidirectional causal effect in the low-fear regime for the S&P 500 which also highlighted that VIX have a stronger pricing effect on S&P 500. However, there was no lead-lag relationship between VXN and NASDAQ-100 index.

Dhanaiah *et al.*, (2012) presented the study to investigate the contemporaneous negative and asymmetric relationship between volatility index and market return in Indian context. The study employed the OLS regression method on the daily closing prices of IVIX and Nifty index over the period from 2009 to 2011. The results of the study showed that there was an inverse relationship between changes in IVIX and Nifty. The study provides evidences of an existence of significant asymmetric relationship between volatility index and Nifty index return.

Kumar (2012) conducted the study to examine the properties of IVIX and its relations with the Indian stock market and the predictive power of IVIX for forecasting future variance. The study employed quantile regression and VAR methodology to examine the results on the daily closing values of the IVIX and the Nifty index to the period 2007 to 2010. The results of the study revealed that the IVIX returns were negatively related to the Nifty index returns on an average. The results also indicate that although IVIX is an unbiased estimator of future realized volatility but contained important information about future market volatility. The study also highlighted that overnight volatility changes in the US market have significant effect on Indian market volatility but not vice-versa. However, the volatility of Japanese stock market neither influence Indian market volatility nor is influenced by Indian market volatility.

Narwal *et al.*, (2012) worked to explore the spillover and transmission of implied volatility for emerging and mature stock market by using the weekly data of implied volatility indices of India, USA, Germany, France, and Switzerland over the period from 2007 to 2011. The result of the study revealed that there was an existence of asymmetries in implied volatility indices of the sample countries. Taken into consideration, the result of the BEKK-GARCH model stated that the conditional variance of IVIX, VDAX, VSMI, and IVIX were strongly affected by their own past shocks and volatility effects. Furthermore, there was an existence of bidirectional shock spillover among Indian-Swiss and Indian-French markets and volatility transmission between Indian-French markets but there was unidirectional spillover from Germany to India and India to America and volatility transmission from India to Switzerland and India to America. Besides, the result of the DCC-GARCH model revealed that there was a moderate level of correlation between mature and emerging volatility indices.

Sarwar, G. (2012) documented the research to examine the intertemporal relationship between VIX and stock market return of US and BRIC countries by using the daily closing

value over the period from 1993 to 2007. The study employed the multivariate regression method and found that there was a strong negative contemporaneous relationship between innovation in VIX, US and Brazilian stock market which is stronger when VIX was high and more volatile. In addition, there was a significant negative contemporaneous relation between volatility index (VIX) and return of China, Brazil and US stock markets during 1993-2007 and for Indian stock market during subsample period of 1993-1997. However, an asymmetric relation was also found between VIX and daily stock market return of US, China and Brazil during 1993-2007 and the relation was weak when VIX was large and more volatile. On the basis of the result, the study highlighted that VIX acts as an investor fear index for Brazil, India and China equity markets along with US stock markets.

Chen, Y., & Lai, K. K. (2013) presented the study to investigate the dynamic relationship of VHSI with both HSI return and future realized volatility of HSI employing Kalman filter. The study used the daily data of VHSI, HSI, VIX and S&P 500 indices over the period from 2001 to 2011 and revealed that there was an existence of a negative and asymmetric contemporaneous relation between VHSI changes and HSI returns. Moreover, the results showed that this asymmetric effect was stronger in Hong-Kong than that in US market. The study also provide evidence that VHSI was an unbiased and efficient estimate of future realized volatility and contains information for the future realized volatility when using monthly data.

Fernandes *et al.*, (2014) explored the time series properties of the VIX at daily frequency from 1992 to 2013. The study employed parametric and semi parametric HAR process for modelling and forecasting purposes. The study also include multi-period returns on the one-month oil future contracts, the term spread, the change in the foreign value of the USD, the credit spread and the difference between the effective and target federal fund rates. The result of the study revealed a strong negative relationship between the VIX index and the S&P 500 index return as well as a positive contemporaneous link with the volume of the S&P 500 index. Moreover, there was an inverse relationship of the VIX index with the term spread, when possible multi colinearity and endogeneity are controlled for. In addition, the study also presented that VIX index does not seem to depend much on the deviation in the Fed rates, the USD index, the changes in oil prices and the credit spread.

Bentes, S. R. (2015) presented the research to investigate the ability of GARCH forecasted and implied volatilities to predict realized volatility in financial markets namely India, Hong-

Kong, US and Korea. The study employed the monthly closing prices of implied volatility and their underlying stock indices of the sample countries over the period from 2003 to 2012 and used OLS to examine the results. The study highlighted that in case of India and Hong-Kong, implied volatility is more efficient than past realized volatility to forecast current realized volatility but not in US and Korea. However, the results were not applicable for the GARCH forecasted volatility model. The study also showed that implied volatility contained at least some information on future realized volatility for all the countries. Moreover, the result of out of sample analysis clearly revealed that GARCH forecasted volatility outperform the implied volatility in forecasting the actual realized volatility between 2010 and 2012.

Chandra & Thenmozhi (2015) conducted the study to investigate the asymmetric effect of India VIX in the Indian stock market and test whether it captures spot volatility better than standard measure of stock price volatility. The study used the daily closing values of India VIX and Nifty index over the period from 2009 to 2012 and employed linear and quantile regression to examine the results. The study revealed that Nifty returns were negatively related to changes in India VIX levels, but in case of high upward movements in the market, the return on the two indices tend to move independently. However, when the market takes sharp downward turn, the relationship was not as significant for higher quantiles. In addition, India VIX captures stock market volatility better than traditional measures of volatility including ARCH/GARCH class of models. The study also highlighted that when India VIX increases (decreases) than switching to large-cap (mid-cap) portfolio by a certain percentage point can be useful for maintaining positive returns on a portfolio.

Kourtis *et al.*, (2016) presented the research for comparison of predictive ability of the realized, implied and GARCH volatility models in different market conditions and forecasting horizons. The study employed the daily dividend adjusted closing prices, realized volatility series constructed from equally spaced 5-minute intraday returns and daily data on implied volatility of 13 indices from 10 countries over the period from 2000 to 2012. The study used the univariate MZ regression and encompassing regression to examine the results. The result of the study highlighted that ranking of model remains similar across countries but varies with the forecast horizons. The heterogeneous auto regressive model offers the most accurate predictions for deriving 1-day ahead forecast while an implied volatility model that incorporates the volatility risk premium was more suitable for monthly forecasts. However, GJR-GARCH models have inferior performance for almost all cases considered. Moreover, performances of all considered models were significantly worse during the period of 2008-09

crises. The study also revealed that implied volatility forecasts can significantly enhance international portfolio choices over the historical methods.

Shaikh, I., & Padhi, P. (2016) worked on the asymmetric contemporaneous relationship between India VIX and S&P CNX Nifty Index by using the daily closing prices over the period from 2007 to 2013. The study also analyzed the seasonality of India VIX in the form of day-of-week effects and option expiration cycle. The study employed the OLS method and revealed that there was significant increase in the level of VIX caused by negative return shocks than the positive return shocks. Moreover, the magnitude of the impact of negative and positive return shocks also observed to be asymmetric; the absolute negative return shocks are larger than positive return shocks. The study also showed that India VIX holds seasonality and on the opening day of market, India Vix at its high level and for the subsequent days it remains low while in the case of option expiration day it remains normal.

Smales, L. A. (2016) presented the study to investigate the relations between changes in VIX, aggregate news sentiment and S&P 500 index returns considering the data from the period 2000-2010. The result of the OLS method revealed that there was an existence of significant negative relationship between changes in VIX and aggregated news sentiment and the association is stronger during financial crises period of 2008-09. The study also highlighted that the asymmetric relation between changes in VIX and S&P 500 returns. There was also an evidence of a stronger relationship between returns and news sentiment during crisis periods and suggested that the asymmetry of the relations between changes in VIX and stock returns holds even when news sentiment is controlled for. Moreover, VAR analysis of the dynamics and cross-dependencies between variables revealed a strong positive relation between previous and current period changes in implied volatility and stock returns, while current period and lagged news sentiment has a significant positive (negative) relationship with stock returns (changes in VIX). Empirical evidences suggested that VIX appears to perform better than news sentiment measures in forecasting future stock market returns.

Bekiros *et al.*, (2017) presented his research to evaluate the effect of innovation in sign and size of the return on the expectations of daily changes in volatility. The study employed OLS and Quantile regression methods to examine the result by using the daily data of implied volatility and their underlying stock exchanges of 20 emerging and developed financial markets over the period from 2000 to 2014. The study showed that conditional contemporaneous relation of return and volatility varies on the basis of sign and size of the

expected return. Moreover, there was an existence of asymmetric and reverse return-volatility relation in many advanced, European, Asian, Latin-American and South-African markets. However, the US market shows the highest reaction to price falls while Asian markets displays the lowest sensitivity to volatility expectation and the Euro area shows similar response in terms of direction and impact. Besides, the Quantile regression analysis presented that the asymmetric relation varies especially in the lowest/highest quantile ranges.

Biktimirov, E. N., & Wang, C. (2017) conducted the research to compare the information superiority of volatility predictions produced by Model free implied volatility (MFIV), Black –Scholes implied volatility (BSIV) and GJR-GARCH volatility forecast. The study employed the daily data of implied volatility and their underlying stock indices of 13 countries namely US, Canada, Australia, Germany, the Netherland, Euro zone, France, Japan, India, Hong-Kong, Switzerland, Korea and United Kingdom over the period from 2005 to 2016. The result of the in-sample analysis revealed that both MFIV and BSIV provide significant information content but neither can completely contained volatility information from the GJR-GARCH model. However, Black-Scholes implied volatility dominates Model-free implied volatility for predicting future volatility. The out of sample forecasting analysis confirms this conclusion. In addition, BSIV tends to provide more-accurate next month volatility forecasts than GJR-GARCH and MFIV. Extensive robustness tests such as P-statistic and six loss functions were also support this conclusion.

Pati *et al.*, (2017) presented the research to determine how behavioral loss-aversion principle can be utilized to describe the asymmetric relation between volatility indices and stock market return under different volatility regimes. The study employed the daily closing prices of stock index and their underlying volatility indices of India, Australia, United Kingdom and Hong-Kong over the period from 2008 to 2015 and used OLS regression and GJR-GARCH methodologies to examine the result. The study revealed that volatility indices moves in opposite direction in response to stock index return and negative market return have higher impact on changes in volatility indices than positive return. However, this negative relation was strongest for UK followed by Australia, Hong-Kong and India. The study also revealed that asymmetric effect is stronger for low volatility regime comparative to medium and high volatility regime for all the countries except United Kingdom and strength of the effect is weakest for India and strongest for Hong-Kong. The result of 30-min intraday analysis confirms the daily data results.

Badshah, I. U. (2018) worked to investigate the volatility linkage among US, developed and emerging market by using the daily data of VIX, VXEFA and VXEEM over the period from 2011 to 2015. The author employed VAR framework which shows that shocks in VIX have considerable spillover effect on volatility indices of both developed and emerging market such as VXEFA and VXEEM. The study also showed that shocks in VIX have more influence on emerging market relative to developed market's volatility index. However, the shocks generated in volatility indices of emerging and developed market have no effect on VIX. Besides, the ADCC-GARCH model revealed that correlation among VIX, VXEFA and VXEEM were time-varying. The dynamic conditional correlations between the three markets were increases (decreases) during turbulent (tranquil) periods.

Bekiros *et al.*, (2018) documented the research to investigate the risk-return relationship in financial markets applying emotional and formal cognitive analysis by using Granger causality test in VAR and the OLS regression methods. The study utilized the daily prices of implied volatility indices and their underlying market indices of 20 countries including advanced, emerging, Asian and Latin American markets over the period from 2000 to 2014. The study highlighted that there was a non-linear and asymmetric risk-return dependence structure in the financial markets of all countries but relationship differs significantly across regions. Moreover, most advanced especially Japanese and US as well as emerging market exhibit a dramatic increase in fear sentiment towards big losses while conditional positive market return fuel aggregate market exuberance at a lower degree. However, the Asian market revealed normal anxiety towards imminent big losses but low exuberance when big profits are expected. The study also presented that global spillover and contagion effects were transferred unidirectional from the United States markets to the other markets. Similarly, there was an existence of significant volatility spillover from European Union advanced markets to the emerging markets and unidirectional causality from Mexican to the advanced as well as Asian markets.

Economou *et al.*, (2018) worked on hidden co-integration approach to uncover the asymmetric relation between fear indices and stock indices of developed markets namely US, Germany and UK. The study used the daily data of implied volatility indices such as VIX, VDAX and FTSE and stock market indices such as S&P 500, DAX 30 and FTSE 100 for the period from 2000 to 2014. The study highlighted that innovation in the US stock market have overall asymmetrical effect on fear index. However, in case of UK and Germany, asymmetry was detected in terms of size and the time span of the adjustment process. Moreover, the time

needed for the residual value to be transferred to the fear index following positive changes in the stock markets and the process to be completed is longer than 2 days for the United Kingdom and Germany, which is much longer than the time needed in the event of negative changes in the stock markets.

Pati *et al.*, (2018) presented the research to determine whether volatility index contains incremental information respective to the GARCH family methods in forecasting volatility of stock markets of India, Hong-Kong and Australia. The study used the daily closing data of volatility index and stock market of the sample countries over the period from 2008 to 2016. The result of the study documented that inclusion of volatility index in the conditional variance equation of GARCH family methods reduces volatility persistence and significant positive coefficient of volatility index showed that implied volatility index contains pertinent information in describing the volatility process. In addition, the univariate MZ regression documented that implied volatility index is a biased forecast but holds pertinent information in explaining future realized volatility. Furthermore, the encompassing regression showed that implied volatility contains relevant information for forecasting stock market volatility beyond the information contained in the GARCH family model forecasts.

Velev *et al.*, (2018) examined the return-volatility relationship across different asset classes and geographical markets by using GARCH model. The study employed the daily data of volatility index and their underlying stock return of different regions such as United States, Asian pacific region and European Union, oil and gold ETF and USD-EUR currency ETF for the period from 1998 to 2011. The result of the study showed that fluctuation in volatility were largely caused by decrease in stock prices rather than increase in prices and negative price moves were the reason of increased volatility. In case of commodities, upward price moves also perceived unfavorably along with negative price moves while for currencies investors were scared of drops in euro prices. In addition, the study also highlighted that volatility in first tier market explains a large portion of volatility in second tier markets so volatility is transferred from first tier markets to second tier markets and it is also similar for the currency and commodity markets.

Aggarwal, S., & Raja, A. (2019) investigated the co-integration relation among the stock markets of BRIC nations and the implied volatility transmission between implied volatility index of India and three other sample countries. The study employed the daily data of volatility indices and their underlying stock indices of BRIC nations from 2008 to 2015 for

the purpose of the study. The result of the Johansen's co-integration test confirmed the presence of the long-run co-integration relationship among the stock market of BRIC nations. Moreover, VECM provides evidences that Brazilian market was affected by Chinese, Indian and Russian markets. However, Indian market was not affected by Brazilian, Russian and Chinese markets similarly Russian and Chinese markets were not affected by Brazilian and Indian markets. Furthermore, the results of variance decomposition test concludes that the indices of Brazil, China and Russia can explain on average 4, 0.5 and 5 per cent of the forecast error variance of India, and India can explain on an average 6.7, 5 and 3 per cent of the forecast error of indices of Brazil, China and Russia, respectively.

Chun *et al.*, (2019) conducted the study to examine the information efficiency of various historical and implied volatility measures in the Korean market. The study used the daily data from 2009 to 2018 and employed univariate and encompassing regression tests to compare the forecasting performance and information content of GARCH-family volatilities, OTM and ATM implied volatilities, lagged realized volatility and the VKOSPI. The results of the study revealed that historical and implied volatility both have good predictive ability, but are biased estimators of future volatility. Furthermore, the information content of the implied volatility constructed from slightly OTM options encompasses that of the deep OTM and ATM options. The study also concludes that generally VKOSPI exhibits the best forecasting performance among the volatility measures analyzed in this study. However, incorporating GJR-GARCH volatility, which exhibits the best performance among the GARCH family volatilities, in the prediction model possibly, improves the explanatory power of the VKOSPI.

Li *et al.*, (2019) used intraday data to examine the validity of Shanghai Stock Exchange's revised iVX and the return-volatility relationship by employing high frequency 1-minute data of iVX and SSE 50 ETF in China over the period from 2015 to 2018. The study employed Quantile regression and Ordinary Least Squares (OLS) methods to examine the results. The result of the study highlighted that iVX was an effective barometer of short-term volatility and shows strong correlations with contemporaneous realized volatility. Moreover, the quantile regression method revealed that there was an asymmetric return-volatility relationship and the relation was more significant in the upper quantile of changes in iVX. It also showed that iVX can be used as a valid "fear index" when there is a panic during the period of market decline. In addition, result indicates that the trading strategies based on iVX outperform those which are based on MACD and KDJ rules.

Sharma *et al.*, (2019) worked in his study on the level of return and volatility linkage among the VIX of BRICS's equity markets. In the study, the author used the daily price data of BRICS's VIX over the period from 2011 to 2016 which was denominated in USD. The result of the Granger Causality test showed that there was bidirectional causal relation and VECM also revealed high linkage in return and volatility among VIX of sample countries. Besides, the asymmetric DCC-GARCH model revealed that intertemporal linkage was low when there was a crisis in the market while linkage was high when the market was stable. Moreover, the Diebold and Yilmaz's methodology also showed that the contribution to its forecast error variance for each sample country was from shocks given to its own VIX return and volatilities. However, cross market spillover was small for each individual country but together the VIX of sample countries showed high degree of connectedness.

Akdag *et al.*, (2020) examined the volatility spillover effect between the VIX and RISE index of Turkey by using the weekly data over the period from 2010 to 2018. The result of the Granger causality test revealed that there was unidirectional causal relation from the VIX to the RISE index but not vice-versa. Moreover, the Breitung and Candelon causality test suggested that causality was permanent because there was existence of a short, medium and long-term causal relation from the VIX to RISE index. It also revealed that there was unidirectional volatility spillover effect from the VIX to the RISE index.

Banerjee, A. (2020) conducted the study to fit a forecasting model on India VIX by using ARIMA for forecasting future value of India VIX which would be useful for getting a view about investor sentiment in near future. The study considered the daily closing prices of India VIX over the period from March 2009 to October 2016 for fitting the model and from November 2016 to October 2017 for validating the model. The study revealed that ARIMA is the reliable model for forecasting future value of India VIX which would be very useful for predicting investor sentiment in coming days. This will be extremely useful for investors in taking investment decisions.

Dai *et al.*, (2020) documented the research to investigate the role of stock market implied volatility to predict stock return realized volatility in five developed countries namely US, UK, France, Germany and Japan. The study used the daily data of S&P 500, CAC 40, DAX 30, NIKKEI 225 and FTSE 100 and monthly data of their volatility indices over the period from 2000 to 2017 and used ordinary least squares method for the purpose of the study. The result of the in-sample analysis showed that there was an existence of unidirectional causality

from stock market implied volatility to stock volatility. Moreover, the out-of-sample analysis provides evidences that stock market implied volatility were significantly more powerful for stock volatility than the oil price volatility in all the sample countries. In short, results from in-sample and out-of-sample documented that the stock market implied volatility has significant predictive power for stock return volatility.

Gaur *et al.*, (2020) examined the relationship across stock returns, volatility and trading volume in Indian stock market. The study used the daily data of Nifty 50, India VIX and trading volume from 2009 to 2018 and adopted quintile regression methodology. The study revealed that asymmetric impact of returns was estimated on volume and volatility changes. The result of the M-WALD granger causality test revealed that trading volume was unidirectionally caused by negative returns and VIX. In addition, the strong asymmetric relationship of stock return was found on volume and volatility. The study concluded that the contemporaneous negative relationship between volatility and volume changes shows that Indian market is dominated by risk averse and informed investors.

Mittal *et al.*, (2020) presented the study to examine the symmetric and asymmetric relation between market return and volatility indices of American, Asian and European markets by using the daily closing value of stock markets and their volatility indices over the period from 2009-2012. The study revealed that there was an existence of strong negative contemporaneous relation between implied volatility indices and their underlying stock market returns which was also symmetric for volatility change sign. Moreover, there was an existence of asymmetric return volatility relation in America, India and Switzerland while in case of France, Germany, Japan and European countries, asymmetric relation was not observed. Furthermore, result of the Granger causality test showed that changes in volatility indices have no effect on market returns for all countries except for the Japanese markets in which a negative and inverse relation was found between changes in implied volatility and market return.

Yang *et al.*, (2020) worked on the network of global volatility spillover and construct time varying systemic risk across global financial markets. The study employed the daily data of implied volatility indices of US, UK, German, Japanese, Korean, Swiss, Hong-Kong, French and emerging markets over the period from March 2011 to 2018. The author used generalized forecast error variance decomposition of VAR model to examine the result. The study revealed that along with US, French, German and emerging stock markets were net sender of

volatility spillover but US is the centre of network and plays a dominant role in spreading volatility to other markets. Furthermore, the US monetary tightening was an important catalyst for intensifying global systemic risk after controlling risk and business cycle factors.

3. RESEARCH GAP

After reviewing the literature it was observed that most of the studies conducted so far have emphasized more on American and other developed markets' volatility indices and little evidence have been found on Indian volatility index. The researchers considered developed markets' volatility indices to discuss its impact and linkages with other markets' volatility indices. So, in the proposed research study, the focus will be upon Indian VIX and its linkage with volatility indices of 11 specified financial markets under consideration. This type of research studies have been conducted more in developed financial markets like American and European markets but a little emphasis have been found on Asian markets, especially India, which motivates us to investigate in Indian context. Moreover, mostly the researchers have used the time series data till 2015 for the research purpose as there are negligible research studies based on the recent time frame. So, in this proposed research study efforts will be made to consider the latest time series data. In addition, the study also extended the literature and provides a comprehensive view by incorporating 12 specified financial markets volatility indices along with India to examine their forecasting ability and risk-return relationship with their underlying stock exchanges. Hence, it provides a significant research gap to conduct the study under consideration.

4. RELEVANCE OF THE STUDY

In India, after LPG policy of 1991, due to increased market integration, any event occurring in one economy has an impact on the economy of other countries. Likewise, Asian crises of 1997, Energy crises of 2000 and sub-prime crises of 2007 have its impact on global markets and now as we can see corona virus was originated in China but got transmitted in all the other countries and became a global crisis. Similarly, any disturbance or event in a country's financial market has its impact on other countries' financial markets. India is the second largest emerging economy in the world and investors receive a lot of interest in India as an investment avenue. Now investors not only invest in their own country but also in other countries for diversification benefits. Since, investor prefers global markets for investments but they are also concerned about the risk in a particular country and its spillover to other financial markets. Implied volatility index is the measure of forward looking volatility which

is based on the prices of derivatives which provides a lot of information about investors' sentiments. Volatility indices are the measures of risk. So, the findings of this proposed research study would be beneficial for the policy makers, risk managers, portfolio managers, academicians and investors to determine the linkage and interdependence of financial markets to formulate policies for investment opportunities and risk management and to take preventive steps to minimize the effect of negative events.

5. RESEARCH OBJECTIVES

The main objective of the study under consideration is to examine the interdependence between Indian and international financial markets. The main objective will be achieved by following the sub-objectives:

i) To examine the return-volatility relationship between stock indices and their underlying implied volatility indices of selected financial markets**;**

ii) To examine the linkage between volatility indices of India and other selected financial markets; and

iii) To examine the role of implied volatility indices to predict stock market volatility of selected financial markets.

6. RESEARCH METHODOLOGY

The research methodology enables the readers to critically evaluate the validity and reliability of the study to draw a meaningful conclusion. The methodology answers the question regarding research design, collection of data and statistical techniques used for the analysis of data in the study. So in research issues, it plays a critical role.

6.1. Research Design

The research design is theoretical description of the methods and techniques for collection, measurement and analysis of data. The present study will be descriptive and empirical in nature.

6.2. Sample Data

The time series data of implied volatility indices and their underlying stock index prices of 12 international stock exchanges considered in this proposed study. The implied volatility

indices of major international markets are used to explore the implied volatility spillover phenomenon between the Indian implied volatility index and the international markets. The table given below presents the details regarding the almost publicly available volatility indices of major stock markets used in the study.

- **List of volatility index and their underlying stock index used in the study**

Name of Country	Volatility Index	Underlying Index	Exchange	Launch Date
Australia	A-VIX	S&P/ASX 200	Australian Securities Exchange	Sept 2010
Brazil	VXEWZ	MSCI Brazil index fund (EXZ)	CBOE	March 2011
China	VXFXI	FTSE China index fund (FXI)	CBOE	March 2011
Germany	VDAX-NEW	DAX	Deutche Borse	April 2005
Hong-Kong	VHSI	Hang-Seng	Hong-Kong Exchange	Feb 2011
India	IVIX	S&P CNX Nifty	National Stock Exchange	July 2010
Japan	VXJ	Nikkei 225	Osaka Exchange	Nov 2010
Korea	VKOSPI	KOSPI 200	Korea exchange	April 2009
Major market in 9 Euro countries*	VSTOXX	EURO STOXX 50	STOXX/Eurex Exchange	April 2005
Russia	RVI	RTS	Moscow exchange	Nov 2013
Switzerland	VSMI	SMI	SIX Swiss Exchange	April 2005
USA	VIX	S&P 500	CBOE	Sept 2003

*Note: * Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, and Spain.*

6.3. Source of Data and Period of the Study

The study under consideration will be based on secondary data. The secondary data will be collected from the official websites of the respective countries, CMIE database prowess and websites of Yahoo Finance and Investing.com etc. The stock exchanges of different countries introduced their volatility indices on different dates. So, the study concerned takes a common period of the study to reach the conclusions of the study. The study covers the period from January 2014 to December 2021 which is subject to increase or decrease as per the requirements of the study.

6.4. Statistical Techniques

The collected data will be analyzed and interpreted with the help of ordinary least squares method, GARCH models, ARIMA models, quintile regression and various other statistical tools and techniques as per the requirement of the study.

7. TENTATIVE CHAPTER SCHEME

The tentative organization of the study i.e. chapter scheme will be as under:

Chapter -1: Introduction

The first chapter discussed about the concept and background of implied volatility indices.

Chapter- 2: Review of Literature

In this chapter, literature related to topic will be reviewed to support the present study. With the help of this review, research gap will be highlighted between the variables taken for the proposed research study.

Chapter- 3: Research methodology

This chapter will provide a quick glance on research process to be followed to achieve the objectives of the study. The chapter will also contain the information on all statistical tools to be used for analysis and interpretation of data during the course of the study.

Chapter- 4: Data Analysis and Interpretation-I

This chapter will include the analysis and interpretation of collected data to achieve the objective of the investigation of relationship between volatility indices and their underlying stock indices of selected financial markets.

Chapter- 5: Data Analysis and Interpretation-II

This chapter will include the analysis and interpretation of collected data to achieve the objective of linkage in India and other selected financial markets.

Chapter- 6: Data Analysis and Interpretation-III

This chapter will include the analysis and interpretation of collected data to achieve the objective of the investigation of predictive ability of implied volatility indices to predict stock market volatility.

Chapter- 7: Findings and Recommendations

This chapter will summarize the major findings of the study. It will also provide some recommendation based on research findings, which is the goal of this research proposal. Further suggestions will be provided.

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